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NASA SAFETY STANDARD FOR UNDERWATER FACILITY AND NON-OPEN WATER OPERATIONS



Washington, D.C. 20546

PREFACE

NASA Safety Standard for Underwater Facility and Non-Open Water Operations

Effective Date:

The NASA Underwater Facility and Non-Open Water Operations standard establishes the minimum safety requirements for all NASA neutral buoyancy facilities, equipment, personnel, and operations involving underwater activities that provide simulation of a weightless environment.

This standard applies to the underwater weightlessness simulation facilities operated by NASA or under contract to NASA, to non-NASA facilities where NASA personnel will participate, to NASA program safety-critical functions tested underwater in a simulated weightless environment, and to underwater test subjects, training, and test team activities in which NASA employees participate. Specifically excluded are operations occurring in natural bodies of water and those conducted from vessels under the jurisdiction of other Federal agencies. This standard is not a direct instruction to NASA contractors, but provides guidance to the responsible NASA Center on the safety assurance required for neutral buoyancy facilities and human underwater activities.

Similar requirements for NASA contractor services in support of neutral buoyancy operations where NASA personnel will participate shall be made applicable to the company or supplier by appropriate contract clauses.

This standard expands on NHB 1700.1(V1), "NASA Basic Safety Manual," policy and guidelines for safety assurance, and the associated quality assurance, medical, and other organization functions to be implemented by NASA Centers for neutral buoyancy facility projects, equipment and supplies, and facility research operations. These requirements shall not supersede any more stringent requirements separately imposed for specific facilities, equipment, or functions by NASA and Occupational Safety and Health Administration (OSHA) directives or other specifications and standards. For NASA contract and contractor operations, the safety and health requirements of NHB 1700.1(V1) shall apply.

Waivers to this document will be processed in accordance with procedures in NHB 1700. 1(V1).

This standard is issued in looseleaf form and will be revised by page changes.

Comments or suggestions concerning the application of these requirements to specific projects should be referred to the National Aeronautics and Space Administration Headquarters, Director, Safety Division, Office of the Associate Administrator for Safety and Mission Quality, Washington, DC 20546.

A handwritten signature in black ink, appearing to read "G. A. Rodney".

George A. Rodney
Associate Administrator for
Safety and Mission Quality

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RECORD OF CHANGES

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CHAPTER 1: RESPONSIBILITIES

100 SYSTEM SAFETY PROGRAM

NASA Centers shall establish an effective system safety program for all neutral buoyancy facility development and modification projects, associated human underwater activities and equipment, and research operations in compliance with NHB 1700.1(V1) and this standard.

- a. NASA Centers shall designate and assign system safety program responsibilities to a Safety, Reliability, and Quality Assurance (SR&QA) organization office that is independent from the underwater neutral buoyancy facility (user) management.
- b. System safety analysis shall be performed and documented for all facilities, human testing equipment, and procedures within the scope of this standard that perform a critical function (including their integration). As a minimum, hazard analysis reports shall document:
 - (1) A listing of all credible hazards.
 - (2) Specific controls for the identified hazards.
 - (3) Verification of the hazard control implementation.
 - (4) Acceptance of the residual hazards by appropriate Center management.
 - (5) Specific safety requirements.
- c. The Center safety office shall require additional system safety analyses when appropriate to support the hazard listing. These may include:
 - (1) Preliminary Hazard Analysis.
 - (2) System Hazard Analysis.
 - (3) Operating Hazard Analysis (also known as an Operating and Support Hazard Analysis).
 - (4) Failure Modes and Effects Analysis.
 - (5) Common Cause Failure Analysis.
 - (6) Fault-Tree Analysis.

d. Test Safety.

- (1) Test Readiness Review Board approved procedures and practices shall be developed and available for use before facility test team and support personnel training and the start of all hazardous operations (Paragraphs 300 and 302 of this standard).
- (2) A Test Safety Officer shall advise the Test Director of any activity that represents clear or present danger to any person or property.

101 QUALITY ASSURANCE PROGRAM

NASA Centers shall provide quality assurance functions to verify conformance with the documented requirements for neutral buoyancy facility development and modification, human underwater activities and equipment, and the associated test and facility operating procedures cited in Paragraphs 300, 301, and 302 of this standard.

- a. NASA Centers shall designate and assign quality assurance responsibilities to an SR&QA organization office that is independent from the underwater neutral buoyancy facility (user) management. Well-defined quality and inspection procedures and guidelines shall be established, available, and understood by all test team personnel before any human underwater or training activities.
- b. A quality assurance representative shall be assigned to perform the following functions:
 - (1) Develop and maintain the facility project quality assurance plan and Center procedures and checklists necessary to implement its provisions.
 - (2) Review, verify, and approve all proposed facility modifications, repair, and nonroutine maintenance for impact on the facility configuration.
 - (3) Review and approve all facility work authorization documents.
 - (4) Assist in the operational readiness inspection of the facility and systems, and document any nonconformance. Verify that all facility and unique human testing equipment is adequate to support the test objectives.
 - (5) Review and approve all nonconformance report dispositions and resolutions.
 - (6) Review and approve all test and training procedures and facility operating procedures (Paragraphs 300 and 302 of this standard).

- (7) Verify that all instruments are in proper calibration and that instruments without valid certification are withheld from use.
- (8) Verify the certification of all facility pressurized systems and components in use and their compliance with NMI 1710.3, "Design, Inspection, and Certification of Pressurized Vessels and Systems," and 29 CFR 1910, Subpart T (Section 1910.430) as applicable.
- (9) Verify that all diver and hyperbaric chamber breathing air meets the requirements of Compressed Gas Association Pamphlets G-7 and G-7.1.
- (10) Be present or on call within 5 minutes during facility human underwater activities, as required by the Test Readiness Review Board, to monitor and document any nonconformance or deviation from the approved test procedures [Paragraph 102a(12) of this standard].

102 TEST TEAM PERSONNEL RESPONSIBILITIES

- a. The following minimum test team requirements shall be met for human testing at NASA Center neutral buoyancy facilities. These test team personnel requirements are a prerequisite to each human testing or training activity conducted by a facility, unless otherwise indicated.
 - (1) Test Director is the authority in charge of all aspects of the test, including off-nominal and emergency procedures, and is responsible for directing the test team to effectively and safely support the Test Conductor within the scope of the approved test plan. The Test Director must have the support of the Test Safety Officer, Licensed Physician/Medical Representative, and Quality Assurance Representative at or on call within 5 minutes during all suited testing and training operations at the facility.
 - (2) Test Conductor is the principal investigator responsible for normal conduct of the test under Test Director's supervision. This person must have knowledge of the specific facility general operating procedures (Paragraph 302 of this standard) and the responsibilities of each test team member, including any limitations placed on the Test Conductor position.
 - (3) Safety Diver is responsible for the safety of an assigned test person. Two safety divers shall be assigned to each pressure suited test subject. Safety divers shall accompany each utility diver or any other test subject using surface-supplied air as required by the Test Readiness Review Board. The safety diver must have thorough knowledge of all test rules and emergency procedures (Paragraph 300 of this standard) and working knowledge of the pressure suit in use and emergency egress procedures for the specific facility. Safety divers shall be certified by a nationally recognized scuba diver program [Paragraph 102b(4)(a)].

- (4) Other Divers are personnel other than safety divers who breathe with scuba and perform underwater functions such as the installation and removal of test equipment, general safety surveillance of a test area, and the recording of test activities in progress. Other divers must be certified by a nationally recognized scuba diver program and qualified for their specific facility function.
- (5) Suited Test Subject (for suited activities only). Suited person performing underwater test objectives or training functions shall be required to complete a pressure suit familiarization course, including a suit fit check, and qualification by the specific test facility in pressure suit emergency procedures. Standard pressure suit training is available [Paragraph 102b(4)(b)]. A suited person must be certified by a nationally recognized SCUBA diver program or complete equivalent SCUBA training provided by the underwater test facility and be qualified for the specific facility function. Appendix C of this standard provides for the participation of astronauts in non-open water operations conducted at an underwater facility.
- (6) Suit Engineer or Technician (for suited activities only) is responsible for pressure suit and component inspection, checkouts, and maintenance for test use, including assistance with donning and doffing the suit. This person must have knowledge of all pressure suit related instrumentation, environmental control system operation, and monitoring of suit test data, and reports results to the Test Director.
- (7) Audio/Visual System Operators are qualified to ensure accurate transmission and recording of the facility test operations.
- (8) Environmental Control System Operator ensures the test subject is receiving the proper pressure and environmental conditions specified by this standard and other applicable documents and facility safety manual procedures. This operator is required for all facility operations using surface-supplied air for life support.
- (9) Facility Support Personnel are on-deck personnel such as lifting device and equipment operators, hyperbaric chamber operators, etc. They must be trained, qualified, and certified to safely carry out their assigned duties (Paragraph 102b).
- (10) Test Safety Officer is designated by the Center SR&QA organization to advise the Test Director on system safety and all specific test safety matters cited in Paragraph 100 of this standard. The Test Safety Officer shall be on call within 5 minutes during all suited testing and training operations at the facility, and present when required by the Test Readiness Review Board. (See Paragraph 100d(2) for additional responsibilities.)

- (11) Medical Representative is responsible to the Center medical organization. The representative provides medical consultation and advice to the Test Director. The representative shall be certified in accordance with Paragraph 201 of this standard. The representative shall be present before start of human underwater activities, and is responsible to advise the Test Director if he or she believes that the well-being of a diver is being compromised.
- (12) Quality Assurance Representative is designated by the Center SR&QA organization to advise the Test Director on all quality assurance matters cited in Paragraph 101 of this standard. The representative shall be on call within 5 minutes during all suited testing and training operations, and present when required by the Test Readiness Review Board. The representative has the responsibility to monitor compliance, to document nonconformance, to verify facility test procedures, and to advise the Test Director of any equipment malfunctions.
- (13) Utility Diver is a non-suited subject who breathes compressed air from tanks or surface-supplied air hoses to perform underwater simulation of test objectives. The diver must be certified by a nationally recognized scuba diver program and qualified for the specific facility function.

b. Personnel Certification.

- (1) NASA Centers shall establish and maintain requirements for training, qualification, and certification of test team members in accordance with NHB 1700.1(V1), OSHA, this standard, and other applicable documents.
- (2) Training shall be administered in the form of classroom instruction, hands-on training, or on-the-job training, and by periodic drills to maintain proficiency in emergency and off-nominal procedures.
- (3) Certification procedures shall require a demonstration of specific system and equipment knowledge and an understanding of the facility operations capabilities in all possible diving modes. Test team personnel certifications shall be attested to by the appropriate Center management office and documented in the training record. Training for the recertification of personnel shall occur at regular intervals, not to exceed 4 years.

- (4) Standard training programs are available and acceptable for safety to meet the necessary test team personnel certifications for an assigned position. These programs include:
- (a) Certified Scuba Diver Training. The National Association of Underwater Instructors, Young Men's Christian Association, U.S. Navy Diving School, and Professional Association of Diving Instructors are recognized. All initial scuba certification training should provide, as a minimum, 48 hours of training as follows:
 - Cognitive Instruction - 20 hours (physics, physiology, and mishap prevention).
 - Confined Pool Time - 20 hours (development of scuba skills).
 - Open Water Diving - 8 hours (at least five 30-minute scuba dives in environment equal to or worse than working conditions expected to be encountered during the performance of safety diver responsibilities).
 - (b) Pressure Suit Training. For suited test subjects, the NASA standard pressure suit training programs at Johnson Space Center (JSC) and Marshall Space Flight Center (MSFC) are recognized. Note: Subjects must have completed a recognized Scuba Diver Training Course.
 - (c) Hyperbaric Chamber Training. For hyperbaric system operators, the JSC and U.S. Department of Defense training programs are recognized.
 - (d) First-Aid Training. For cardiopulmonary resuscitation and first-aid training, the American Red Cross standard course or equivalent is recognized. The JSC Medical Sciences Division is available to consult on medical considerations for diving fitness of personnel.
 - (e) Lifting Device Training. Normally provided by the Center in accordance with NHB 1700.1(V1), Chapter 6. Operators may be certified by a recognized certification organization in accordance with NSS/GO-1740.9, "NASA Safety for Lifting Devices and Equipment."

CHAPTER 2: REQUIREMENTS

200 FACILITY DESIGN, CONSTRUCTION, CERTIFICATION, AND OPERATIONS

- a. Design and construction of new underwater facilities for research and neutral buoyancy testing shall be implemented in compliance with applicable federal, national, state, and local building codes; this standard; and NASA policy and guidance set forth in NHB 1700.1(V1), “Basic Safety Manual”; NHB 7320.1, “Facilities Engineering Handbook”; and NHB 8820.2, “Facility Project Implementation Handbook.”
- b. Modifications of existing neutral buoyancy facilities, and facilities previously approved by the NASA Center for the final design or construction phases shall be accomplished to maintain compliance with the applicable cited documents.
- c. Unique facility requirements for equipment standards or operating procedures not addressed by OSHA standards shall be developed and maintained by the NASA Center. These shall be based on national consensus standards and good practice techniques to supplement and complement the OSHA standards. NASA supplementary and alternate standards must be approved in accordance with NHB 2710.1, “Safety and Health Handbook - Occupational Safety and Health Programs.” Facility operating procedures shall be maintained as required by Paragraph 302 of this standard.
- d. Neutral buoyancy facilities, including the hyperbaric chamber, shall be certified for human underwater activities by an Operational Readiness Inspection to ensure that the requirements of this document and the Center Facility Safety requirements are met.
- e. Requests for the participation of astronauts in human underwater activities at NASA neutral buoyancy facilities shall be coordinated and approved by the JSC in accordance with Appendix C of this standard.

201 MEDICAL REQUIREMENTS

NASA Center medical organizations shall provide diving medical support, consultation, and the services of qualified medical diving team personnel to support neutral buoyancy facility human underwater and training activities, procedures, and hyperbaric chamber and recompression operations. Well-defined medical emergency procedures shall be established, available, and practiced (at least annually) to ensure that all divers and others

subjected to hyperbaric exposure can be assisted, transported, and treated for air embolism and other barotoma accidents.

a. Licensed Physician.

- (1) The Center medical organization shall have review and signature authority by a licensed physician for all test operating, emergency, and training procedures and their changes (Paragraph 300 of this standard).
- (2) A physician certified in hyperbaric medicine who is designated to support test team operations shall be on call within 5 minutes during any human underwater activity.
- (3) The physician shall administer diver physical examinations and shall certify, at least annually, that all potential underwater personnel are able to perform under hyperbaric exposure. Also, the physician shall administer decompression procedure assessment evaluations and post-dive examinations following an injury or illness that requires hospitalization.

b. Medical Representative.

- (1) A medical representative [Paragraph 102a(11) of this standard], such as a medical technician, shall be designated to support all test team and training operations, and shall be present before the start of any underwater activity.
- (2) Before each test or training activity, a medical representative shall interview all potential underwater personnel and shall refer an individual to the physician for further evaluation as deemed appropriate.
- (3) Medical representatives shall possess current basic life support and hyperbaric physiology certification, including diving medicine certification by a nationally recognized institution, and shall be approved by the Center medical organization as qualified to assist with medical emergencies during underwater activities.

c. Hyperbaric Chamber Systems. NASA neutral buoyancy facilities shall have a hyperbaric chamber available within 5 minutes for suited underwater activity exposures of a combined water depth and depth-equivalent from suit pressure that equals 20 feet or greater equivalent from surface pressure. Facilities that conduct underwater suited activities at lesser pressures or activities using only SCUBA shall pre-arrange access to a fully functioning hyperbaric system, and ensure that a diver can be transported and treated in a timely manner. All hyperbaric systems shall include the personnel, equipment, and supplies essential to initial medical and hyperbaric management

of diving-related mishaps. The following personnel are required for hyperbaric system operations:

- (1) Hyperbaric Chamber Operator certified as a chamber operator [Paragraph 102b(4) of this standard].
 - (2) Hyperbaric Chamber Inside Attendants certified in hyperbaric medicine, such as a licensed physician or medical representative.
- d. Limitations on Flying After Hyperbaric Exposure. Decompression sickness may result from flying in the cabin pressure of commercial aircraft after using compressed air for underwater diving activities. Decompression sickness can occur even after “no decompression” diving, unless adequate time on air or oxygen is allowed before exposure to a reduced atmospheric pressure. These situations are not comparable to altitude bends, because larger amounts of nitrogen are present after a dive. Therapy should therefore be assumed to be required in decompression sickness generated by flying after diving. The following limitations will apply:
- (1) Single dive or hyperbaric exposure not exceeding 20 feet depth-equivalent - No restrictions.
 - (2) A dive or hyperbaric exposure or repetitive dives within the time and depth parameters of the U.S. Navy no-decompression tables - 12 hours of surface time breathing air or 2 hours of surface time breathing 100 percent oxygen are required before flying at a cabin altitude greater than 8,000 feet above mean sea level.
 - (3) A dive or hyperbaric exposure or repetitive dives that require a staged decompression procedure in accordance with the U.S. Navy decompression tables - 24 hours of surface time are required before flying.
 - (4) Personnel engaged in compressed breathing gas activities other than the conditions specified above (including scuba, surface-supplied air diving, and hyperbaric chamber exposure) shall not participate in aerial flight or hypobaric chamber ascent within 24 hours.

These limitations are not intended to restrict Center research conducted with the approval of an established Human-Use Committee.

202 PERSONNEL SUPPORT EQUIPMENT REQUIREMENTS

- a. Life Support and Environmental Control Systems. Each suited test subject shall have a primary and an emergency breathing air supply. Pressure suit air flow shall be 6-10 cubic feet/minute. Pressure fluctuations shall not exceed 0.4 psig/second. Pressure suit systems shall have dual pressure relief valve protection. Pressure suit cooling shall be provided to correct or prevent a temperature rise in the test

subject work environment. All critical functions for the safety and well-being of the test subject shall have warnings and cautions provided for discrepancy (off-nominal) or safety-critical conditions.

- b. Man Lift Systems. The primary ingress/egress system for pressure suited test subjects shall have a powered lifting device with power source redundancy. The lifting device should not be electric, but an electric lift with adequate protection to preclude unacceptable risk of electric shock to operators and test participants may be used. Stairs shall be used only as a backup system.
- c. Electrical Systems. Underwater tools and equipment shall be limited to 35 Vdc or less. Batteries placed underwater shall be safeguarded to prevent hydrogen outgassing, and shall be packaged to prevent chemical leakage into the water or electric short circuits from water leaks. All electrical system outlets in the facility shall be equipped with ground fault interrupters designed to operate between 4 and 7 milliamperes.
- d. Pressure Suits. Experimental or prototype suits and components shall be treated as a facility test article and meet all safety program review, test documentation, and certified personnel requirements of this standard before each test or series of tests. Standard pressure suits currently approved for flight need not be reviewed, but shall be readied for human testing and maintained in accordance with established procedures.
- e. Communications Systems. Each suited test subject shall have dedicated two-way voice communications with the Test Director workstation at all times.
- f. Test Team Emergency Breathing Air. Each Safety Diver shall have an effective means to provide breathing air underwater to any other non-suited test personnel.

203 ANNUAL SAFETY PROGRAM EVALUATION

NASA Centers and NASA contractor organizations shall, in addition to normal management surveillance, conduct a formal safety evaluation review at least annually to evaluate all neutral buoyancy facility programs for compliance with this standard and sound safety practices.

- a. Center management and the designated SR&QA organization shall establish a competent and qualified evaluation team that will have representatives of the safety, quality assurance, medical, facility user, and other organizations as required. This team may include personnel from NASA Headquarters, other NASA Centers, the Astronaut Office, and supporting NASA contractor organizations as appropriate.

- b. Normally, a status report shall be prepared by the evaluation team, along with any planned corrective action and milestone date responses. This evaluation report shall be submitted to the cognizant NASA Center Director and interested levels of management, to the equivalent NASA contractor management as appropriate, and to the NASA Headquarters Associate Administrator for Safety and Mission Quality (SMQ). Copies of this report also shall be provided to the JSC Astronaut Office and Safety Office if astronauts are to participate in testing or training in the neutral buoyancy facility program being evaluated.

204 RECORDKEEPING AND REPORTING

- a. NASA mishap and Federal OSHA reporting and recordkeeping requirements shall be met according to NASA guidelines contained in NHB 1700.1(V1), Chapter 2.
- b. OSHA 29 CFR 1910, Subpart T (Section 1910.440) shall be followed to record the occurrence of any diving-related injury or illness that requires a NASA test team member to be hospitalized for 24 hours or more. OSHA requirements for the retention of records that pertain to non-open water operations shall be met as follows:
 - (1) Test team member medical reports (by physician) - Retain 5 years.
 - (2) Facility safety manual - Retain current test plans and test procedures only.
 - (3) Depth-time profiles - Retain until the recording of a dive is completed, or recording of a decompression procedure assessment evaluation is completed for a decompression sickness incident.
 - (4) Recording of a dive - Retain 1 year; or 5 years where there has been a decompression sickness incident.
 - (5) Decompression procedure assessment evaluation - Retain 5 years.
 - (6) Equipment inspections and testing records - Retain current record entries or tag, or until equipment is withdrawn from service.
 - (7) Records of hospitalization and treatment - Retain 5 years.
 - (8) Records retained for 5 years - After the 5-year retention period, forward such records to the National Institute for Occupational Safety and Health, Department of Health and Human Services.
- c. NASA Centers shall keep a current record of all maintenance actions accomplished on the facility diving equipment and support apparatus. Copies of these records shall be made available for access to all test team members.

- d. NASA Centers shall make available for access to the test team members all medical records of which the person is the subject as set forth in OSHA 29 CFR 1910.20(a)-(e) and (g)-(i).

CHAPTER 3: PROCEDURES

300 TEST PROCEDURES

- a. Before each new test or new series of tests, including facility training activities, the NASA Center shall establish a Test Readiness Review Board, to be chaired by the neutral buoyancy facility manager or higher management, with membership to include the safety office, medical, and quality assurance representatives; the Test Director or his or her representative; and others as appropriate.
 - (1) All Center-approved test procedures (Paragraph 300b below) shall be made available to the Test Readiness Review Board for review before it convenes.
 - (2) The Board membership shall review and approve the test plan, and shall identify any specific constraints on the use of procedures by the test team.
- b. NASA Center testing or training organizations shall develop and fully document all necessary procedures for safe neutral buoyancy testing and training activities based on the facility mission and test requestor requirements. These procedures and all changes shall have a signature approval for their use by the facility manager; Center-designated safety, quality assurance, and medical offices; and test engineering or other concerned organizations. Test procedures should include, but not be limited to, the following:
 - (1) Operating Procedures shall be written in sufficient detail to identify all hazards and cautions to the test team personnel. The procedures shall be made part of the test plan, and be approved by the Test Readiness Review Board.
 - (2) Emergency Procedures shall prevent personnel injury or illness and minimize damage to equipment in the event of a system failure or discrepancy.
 - (3) Testing/Training Rules shall define all equipment use, instrumentation, and calibration requirements; diver and equipment operating limits; and the operating conditions that will require a diving termination (normal and emergency) or a test hold, or will support proceed-with-test decisions.
- c. The approved test plan and all test procedures shall be available to appropriate test team personnel at their duty stations.

301 PRETEST OPERATIONS

- a. Underwater neutral buoyancy facility pre-dive operations shall include a comprehensive briefing of the test team by a knowledgeable person, familiar with the Safe Practices Manual requirements (Paragraph 302 of this standard) and operational aspects of the planned test or training activity. As a minimum, the briefing will include a review of:
 - (1) Operating procedures, emergency procedures, and the specific testing/training rules that have been approved and reviewed by a Test Readiness Review Board (Paragraph 300 of this standard).
 - (2) All constraints in the Test Readiness Review Board approved test plan.
 - (3) All test articles and hardware to be used and their status.
 - (4) Status of all facility support equipment.
 - (5) Test team member assignments and responsibilities, including all buddy system assignments and emergency personnel.
 - (6) Current certification of all test team personnel for verification by the Test Director.
- b. The pretest checklist shall be completed and verified by the quality assurance representative.

302 FACILITY OPERATING PROCEDURES (SAFE PRACTICES MANUAL)

NASA neutral buoyancy facility procedures (including all safe practices content required by OSHA 29 CFR 1910.420) shall be developed as operation and maintenance instructions. As a minimum, facility operation and maintenance planning will include, but not be limited to, the following:

- a. General Operating Procedures shall be maintained by each facility and describe facility organization and responsibilities, test team workstation positions and certification requirements, facility equipment and outside support requirements, facility maintenance plan, and the testing/training rules for all diving modes of operation.
- b. Standard Operating Procedures shall be maintained by each facility to implement the master equipment list and tool list maintenance and replenishment actions; to prescribe facility planning for proposed facility repairs, rehabilitation and modification, and new construction projects (Paragraph 200 of this standard); and to describe the special handling, storage, transportation, and refurbishment procedures for complex test articles and associated components. Specific operating procedures shall also be documented and employed by each facility for

the following:

- (1) Configuration control of the facility and equipment, including as-built record drawing verification and update, and Center management approval of changes.
 - (2) Routine maintenance actions for the facility and equipment.
 - (3) Calibration recall scheduling or periodic in-place calibration of facility and equipment instruments.
 - (4) Periodic validation of the facility and equipment operation and functional integrity.
 - (5) Facility equipment startup and shutdown.
- c. Facility Emergency Procedures shall be maintained by each facility to cover personnel actions in the event of a facility emergency such as fire, hazardous substance spill, loss of power, earthquake, and medical emergency.

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APPENDIX A

REFERENCES

The following documents are a part of this standard:

- a. NHB 1700.1(V1), NASA Basic Safety Manual.
- b. NHB 2710.1, Safety and Health Handbook - Occupational Safety and Health Programs.
- c. NMI 1710.3, Design, Inspection, and Certification of Pressurized Vessels and Systems.
- d. NSS/GO-1740.9, NASA Safety Standard for Lifting Devices and Equipment.
- e. NHB 7320.1, Facilities Engineering Handbook.
- f. NHB 8820.2, Facility Project Implementation Handbook.
- g. 29 CFR 1910, Occupational Safety and Health Standards.
- h. Compressed Gas Association Pamphlet G-7, Compressed Air for Human Respiration.
- i. Compressed Gas Association Pamphlet G-7.1, Commodity Specification for Air.
- j. American Society of Mechanical Engineers Boiler and Pressure Vessel Code.
- k. American National Standards Institute Codes.
- l. U.S. Navy Diving Manual, Volume 1, Air Diving.

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APPENDIX B

DEFINITIONS

CERTIFIED PERSONNEL. Personnel who have completed required training and whose specified knowledge or proficiency in a skill has been demonstrated and documented.

DIVER. Person working in water using underwater apparatus that supplies compressed breathing gas at ambient pressure.

DIVING MODE. Type of diving activity requiring specific equipment, procedures, and techniques (scuba, surface-supplied air, or mixed gas).

HYPERBARIC EXPOSURE. Underwater pressure conditions in excess of surface pressure.

HUMAN RATING. Incorporation of enhanced environmental support, reliability, and safety features into the design and operation of an underwater facility essential to ensure the preservation of life throughout a human-testing mission.

HUMAN TESTING (TRAINING). Underwater facility operations using scuba, pressure suit, or surface-supplied air for life support during test (training) activities.

NEUTRAL BUOYANCY FACILITY. NASA owned or managed facility housing a pool, tank, or vessel containing liquid and used for research or training in a simulated weightless environment.

ON CALL. Able to be physically present in a facility test area, within a specified period of time, in response to the first call for assistance.

OPERATIONAL READINESS INSPECTION. Formal program review conducted by independent management teams to evaluate all facets of neutral buoyancy facility management and operations support for the safety program, and compliance with existing safety rules and regulations including this standard.

SAFETY-CRITICAL CONDITION. Hazardous condition that may lead to a mishap with severe occupational injury or illness, or major damage or loss of property or equipment.

SAFETY-CRITICAL FUNCTION. Any system, equipment, or facility function that could causes a safety-critical condition.

SCUBA TESTING (TRAINING). Any underwater activity with a test subject using scuba exclusively for life support.

SIMULATED WEIGHTLESS ENVIRONMENT. An environment in which gravity effects on a mass are canceled by adjusting the buoyancy of objects or persons underwater.

SUITED TEST. Any underwater activity with a test subject wearing a pressure suit that is designed for use in a vacuum.

TEST PLAN. Document approved by a Center-designated Test Readiness Review Board that describes the test objectives, test support requirements, test-unique hazards, and the test procedures and acceptable risk alternatives for accomplishing the objectives.

TEST READINESS REVIEW BOARD. A board established by the Center to review, assess, and approve the readiness status of all facility systems, personnel, and documentation for each underwater test or series of tests before the tests begin.

TEST TEAM. All personnel assigned to an underwater facility, scuba testing, or suited test or training activity in accordance with Paragraphs 102 and 201 of this standard.

APPENDIX C

ASTRONAUT PARTICIPATION IN NEUTRAL BUOYANCY OPERATIONS

Requests

Requests for the participation of NASA astronauts in testing conducted at underwater facilities not located at the JSC shall be addressed to the Director, Flight Crew Operations (JSC/CA).

Qualifications

Astronauts selected to participate in non-open water operations shall be scuba qualified if participating in scuba testing and pressure suit qualified if participating in a suited test.

Facility Certification

Astronauts assigned to a specific facility shall meet the test team work position certification requirements of this standard.

Predive Physical Examinations

Astronauts participating in suited non-open water operations shall be administered a brief predive physical examination by a licensed physician before each test or training activity.

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